

## DISPLAY DEVICE

### BACKGROUND OF THE INVENTION

Field of the Invention:

[0001]

The present invention relates to a display device, especially to a liquid crystal display device.

[0002]

Description of the Related Art

Among various types of liquid crystal display devices, there has been known a liquid crystal display device in which out of respective substrates facing each other in an opposed manner with liquid crystal sandwiched therebetween, on respective pixel regions at a liquid-crystal-side of one substrate, pixel electrodes made of transparent conductive layers are formed, and on a liquid crystal side of another substrate, a counter electrode which is made of a transparent conductive layer and corresponds in common to the respective pixel regions is formed, and optical transmissivity of the liquid crystal is controlled based on electric fields generated between respective electrodes, wherein molecules of the liquid crystal are vertically aligned with respect to the substrates when no electric field is applied to the liquid crystal (see Japanese Unexamined Patent Publication 2002-14353, Japanese Unexamined Patent Publication 1999-72793,

Japanese Unexamined Patent Publication 2002-284290, for example).

[0003]

Then, in the liquid crystal display device having such a constitution, there has been also known a liquid crystal display device in which to obtain the broad viewing angle characteristics, the pixel electrode is divided into a plurality of regions thus forming divided electrodes (hereinafter referred to as "sub pixels") and on a liquid-crystal-side surface of a substrate at a side on which the counter electrodes are formed, projecting portions are formed at positions which face the centers of respective sub pixels (see Japanese Unexamined Patent Publication 2002-47217, for example).

[0004]

When an electric field is generated between the pixel electrode and the counter electrode, respective molecules of the liquid crystal on the sub pixel exhibits the behavior of tilting radially using the projecting portion as the center. This is because that due to such a behavior, light which passes through the liquid crystal can be irradiated to a viewer side in a broad range.

[0005]

[0006]

However, with respect to the liquid crystal display device having such a constitution, it has been confirmed that when an

electric field is generated between the pixel electrode and the counter electrode, a cruciform blackish pattern (hereinafter referred to as "extinction pattern") appears as shown in Fig. 12 for every sub pixel of the pixel electrode and hence, the white display is not performed over the whole surface.

[0007]

Inventors of the present invention have pursued a cause of the phenomenon and have eventually found that one one-stroke shaped blackish pattern of the extinction pattern agrees with the direction of a polarization axis of one polarizer out of polarizers which are respectively formed on respective substrates, while another one-stroke shaped blackish pattern agrees with the direction of a polarization axis of another polarizer.

[0008]

It is confirmed that this phenomenon is caused by a fact that when the liquid crystal molecules are tilted in parallel with respect to the substrate, the liquid crystal molecules are collectively tilted along the directions of the polarization axes of the respective polarizers.

[0009]

The present invention has been made under such circumstances and it is an object of the present invention to provide a liquid crystal display device which can obviate the generation of the above-mentioned extinction pattern.

## SUMMARY OF THE INVENTION

[0010]

To briefly explain the summary of typical inventions out of the inventions disclosed in this specification, they are as follows.

Means 1.

The liquid crystal display device according to the present invention is, for example, characterized in that molecules of liquid crystal interposed between respective substrates which are arranged to face each other in an opposed manner are arranged in the vertical direction with respect to the substrate at the time of applying no voltage, and the liquid crystal display device further includes a plurality of protruding portions which are scattered on a surface of one substrate being in contact with the liquid crystal in respective pixel regions, and projecting portions or recessed portions which are provided about these protruding portions, the projecting portions or the recessed portions being substantially aligned with respective polarization axes of one polarizer which is provided to a surface of one substrate at a side opposite to a liquid crystal side and of another polarizer which is provided to a surface of another substrate at a side opposite to a liquid crystal side.

[0011]

Means 2.

The liquid crystal display device according to the present invention is, for example, characterized in that respective substrates are arranged to face each other in an opposed manner with liquid crystal sandwiched therebetween and molecules of the liquid crystal are activated due to electric fields generated between one electrodes which are formed on a liquid crystal side of one substrate out of the respective substrates and another electrodes which are formed on a liquid crystal side of another substrate out of the respective substrates,

the liquid crystal display device includes one polarizer which is provided to a surface of one substrate at a side opposite to a liquid crystal side and another polarizer which is provided to a surface of another substrate at a side opposite to a liquid crystal side, and

one electrode is constituted of a mass of a plurality of sub pixels and includes protruding portions which are positioned at the substantially centers of respective sub pixels on a surface of another substrate which faces the liquid crystal, and projecting portions or recessed portions which are provided about these protruding portions, the projecting portions or the recessed portions substantially being aligned with respective axes of one polarizer which is provided to a surface of one substrate at a side opposite to a liquid crystal side and another polarizer which is provided to a surface of another substrate

at a side opposite to a liquid crystal side.

[0012]

Means 3.

The liquid crystal display device according to the present invention is, for example, characterized in that the liquid crystal display device includes, on each pixel region of a liquid-crystal-side surface of one substrate out of respective substrates which are arranged to face each other in an opposed manner with liquid crystal sandwiched therebetween, a switching element which is driven by scanning signals from a gate signal line and a pixel electrode to which video signals are supplied from a drain signal line via the switching element,

a counter electrode which corresponds in common to respective pixel regions formed on respective pixel regions on a liquid-crystal-side surface of another substrate, and one polarizer which is provided to a surface of one substrate at a side opposite to a liquid crystal side and another polarizer which is provided to a surface of another substrate at a side opposite to a liquid crystal side, and

the pixel electrode is constituted of a mass of a plurality of sub pixels and includes protruding portions which are positioned at the substantially centers of respective sub pixels on a surface of another substrate which faces the liquid crystal, and projecting portions or recessed portions which are provided about these protruding portions, the projecting portions or the

recessed portions being substantially aligned with respective directions of axes of one polarizer which is provided to a surface of one substrate at a side opposite to a liquid crystal side and another polarizer which is provided to a surface of another substrate at a side opposite to a liquid crystal side.

[0013]

Means 4.

The liquid crystal display device according to the present invention is, for example, characterized in that the liquid crystal display device includes, on each pixel region of a liquid-crystal-side surface of one substrate out of respective substrates which are arranged to face each other in an opposed manner with liquid crystal sandwiched therebetween, a switching element which is driven by scanning signals from a gate signal line and a pixel electrode to which video signals are supplied from a drain signal line via the switching element, a counter electrode which corresponds in common to respective pixel regions formed on respective pixel regions on a liquid-crystal-side surface of another substrate, and one polarizer which is provided to a surface of one substrate at a side opposite to a liquid crystal side and another polarizer which is provided to a surface of another substrate at a side opposite to a liquid crystal side, and

the counter electrode is constituted of a mass of a plurality of sub pixels in each pixel region and includes

protruding portions which are positioned at the substantially centers of respective sub pixels and projecting portions or recessed portions which are provided about these protruding portions on a surface of one substrate which is brought into contact with the liquid crystal, the projecting portions or the recessed portions being substantially aligned with respective axes of directions of one polarizer which is provided to a surface of one substrate at a side opposite to a liquid crystal side and of another polarizer which is provided to a surface of another substrate at a side opposite to a liquid crystal side.

[0014]

Means 5.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of any one of means 1 to 4, characterized in that the liquid crystal contains a chiral material.

[0015]

Means 6.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of any one of means 1 to 4, characterized in that the liquid crystal contains no chiral material.

[0016]

Means 7.

The liquid crystal display device according to the present



invention is, for example, on the premise of the constitution of means 3, characterized in that the projecting portions or the recessed portions are formed on a surface of a leveling film which is formed on a surface of another substrate which is brought into contact with the liquid crystal.

[0017]

Means 8.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 7, characterized in that the counter electrode is formed on a surface of a leveling film and the protruding portions are formed on a surface of the counter electrode.

[0018]

Means 9.

The liquid crystal display device according to the present invention is, for example, on the premise of the constitution of means 7, characterized in that the protruding portions are formed on a surface of a leveling film and the counter electrode is formed on a surface of the leveling film such that the counter electrode also covers the projecting portions.

[0019]

Here, the present invention is not limited to the above-mentioned constitutions and various modifications are conceivable without departing from the technical concept of the present invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a constitutional view of an essential part showing one embodiment of a liquid crystal display device according to the present invention and also is a plan view showing pixel electrodes at one substrate side and protruding portions and projecting portions at another substrate side in an overlapped manner; .

Fig. 2A is a plan view showing one embodiment of the whole structure of the liquid crystal display device according to the present invention;

Fig. 2B is an enlarged view showing a portion a in Fig. 2A;

Fig. 3 is a plan view showing one embodiment of a pixel of the liquid crystal display device according to the present invention;

Fig. 4 is a cross-sectional view taken along a line IV-IV in Fig. 3.

Fig. 5 is a plan view of another embodiment of a pixel electrode of the liquid crystal display device according to the present invention;

Fig. 6 is an explanatory view showing the relationship between the direction of projecting portions formed in the liquid crystal display device according to the present invention and the directions of polarization axes of respective polarizers.

Fig. 7 is a plan view of an essential part showing another embodiment of the liquid crystal display device according to the present invention;

Fig. 8 is a plan view of an essential part showing another embodiment of the liquid crystal display device according to the present invention;

Fig. 9 is a cross-sectional view of an essential part showing another embodiment of the liquid crystal display device according to the present invention;

Fig. 10 is a cross-sectional view of an essential part showing another embodiment of the liquid crystal display device according to the present invention;

Fig. 11 is a cross-sectional view of an essential part showing another embodiment of the liquid crystal display device according to the present invention;

Fig. 12 is an explanatory view showing an extinction pattern displayed on a conventional liquid crystal display device.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020]

Preferred embodiments of the present invention are explained in conjunction with drawings which show the embodiments.

Embodiment 1.

<< Whole constitution >>

Fig. 2A is a plan view showing one embodiment of the whole constitution of a liquid crystal display device according to the present invention and Fig. 2B is an enlarged view of a portion in Fig. 2A.

In these drawings, first of all, there are provided a pair of transparent substrates SUB1, SUB2 which are arranged to face each other in an opposed manner with liquid crystal sandwiched therebetween, wherein the liquid crystal is sealed between the transparent substrates SUB1, SUB2 by a sealing material SL which is also served for fixing another transparent substrate SUB2 to one transparent substrate SUB1.

[0021]

On a liquid-crystal-side surface of one transparent substrate SUB1 which is surrounded by the sealing material SL, gate signal lines GL which extend in the x direction and are arranged in parallel in the y direction and drain signal lines DL which extend in the y direction and are arranged in parallel in the x direction are formed.

[0022]

Regions which are surrounded by respective gate signal lines GL and respective drain signal lines DL constitute pixel regions and a mass of these pixel regions in a matrix array constitute a liquid crystal display part AR.

[0023]

Each pixel region includes a thin film transistor TFT which

is operated in response to a scanning signal from one-side gate signal line GL and a pixel electrode PX to which a video signal from one-side drain signal line DL is supplied through the thin film transistor TFT are formed.

[0024]

An electric field is generated between this pixel electrode PX and a counter electrode CT (not shown in the drawings) which is formed on a liquid-crystal-side surface of another transparent substrate SUB2 in common with respect to respective pixel regions and optical transmissivity of the liquid crystal is controlled in response to the electric field.

[0025]

Here, between the pixel electrode PX and another gate signal line GL which is arranged close to the gate signal line GL which is served for driving the thin film transistor TFT of the pixel region, the additional capacitance element Cadd is formed. This additional capacitance element Cadd is provided for holding the video signals supplied to the pixel electrode PX in the pixel electrode PX.

[0026]

Further, the counter electrode CT is configured to be pulled out to the transparent-substrate-SUB1 side surface by way of conductors CL formed on four corners of the sealing material SL.

[0027]

Respective ends of the gate signal lines GL extend beyond the sealing material SL and extended ends constitute terminals to which output terminals of the scanning signal drive circuit V are connected. Further, to input terminals of the scanning signal drive circuit V, signals from a printed circuit board (not shown in the drawings) which are arranged outside a liquid crystal display panel are inputted.

[0028]

The scanning signal drive circuit V is constituted of a plurality of semiconductor devices and a plurality of neighboring gate signal lines GL which are formed into a group and one semiconductor device is allocated to each group.

[0029]

In the same manner, respective ends of the drain signal lines DL extend beyond the sealing material SL and extended ends constitute terminals to which output terminals of the video signal drive circuit He are connected. Further, to input terminals of the video signal drive circuit He, signals from a printed circuit board (not shown in the drawings) which are arranged outside a liquid crystal display panel are inputted.

[0030]

The video signal drive circuit He is also constituted of a plurality of semiconductor devices and a plurality of neighboring drain signal lines DL are formed into a group and one semiconductor device is allocated to each group.

[0031]

The respective gate signal lines GL are sequentially selected one after another in response to the scanning signals from the scanning signal drive circuit V.

[0032]

Further, to respective drain signal lines DL, the video signals are supplied by the video signal drive circuit He at the timing of selecting the gate signal lines GL.

[0033]

Here, in the above-mentioned embodiment, the scanning signal drive circuit V and the video signal drive circuit He are constituted of the semiconductor devices mounted on the transparent substrate SUB1. However, these circuits may be formed of so-called tape-carrier-method semiconductor devices which are connected to each other striding over the transparent substrate SUB1 and the printed circuit board, for example. Further, when semiconductor layers of the thin film transistors TFT are made of poly-crystalline silicon (p-Si), semiconductor elements made of polycrystalline silicon may be formed on a surface of the transparent substrate SUB1 together with wiring layers.

[0034]

<<Constitution of pixels>>

Fig. 3 is a plan view showing one embodiment of a construction of the pixel and Fig. 4 is a cross sectional view

taken along a line IV-IV in Fig. 3.

[0035]

In Fig. 3, first of all, a pair of gate signal lines GL which extend in the x direction and are arranged in parallel in the y direction are formed on the liquid-crystal-side surface of the transparent substrate SUB1.

[0036]

Here, as the above-mentioned liquid crystal, for example, liquid crystal which has a negative dielectric anisotropy and is oriented substantially vertically with respect to the transparent substrate SUB1 at the time of applying no electric field is used.

[0037]

The gate signal lines GL surround the rectangular region together with a pair of drain signal lines DL described later and this region constitutes a pixel region.

[0038]

On the surface of the transparent substrate on which gate signal lines are formed, an insulation film GI (see Fig. 4) which is made of SiN, for example, is formed such that the insulation film GI also covers the gate signal lines GL.

[0039]

The insulation film GI functions as an interlayer insulation film with respect to the gate signal lines GL in regions where the drain signal lines DL described later are formed,



functions as a gate insulation film in regions where the thin film transistors TFT described later are formed, and functions as a dielectric film in regions where capacitive elements Cadd described later are formed.

[0040]

Then, on a surface of the insulation film GI, semiconductor layers AS made of amorphous Si, for example, is formed such that the semiconductor layers AS are overlapped to portions of the gate signal lines GL.

[0041]

The semiconductor layer AS is of a semiconductor layer of the thin film transistor TFT, wherein by forming a drain electrode SD1 and a source electrode SD2 on an upper surface thereof, it is possible to constitute an MIS type transistor having the inverse-staggered structure which uses a portion of the gate signal line GL as the gate electrode.

[0042]

Here, the drain electrodes SD1 and the source electrodes SD2 are formed simultaneously with the formation of the drain signal lines DL.

[0043]

That is, when the drain signal lines DL which extend in the y direction and are arranged in parallel in the x direction are formed, portions of the drain signal lines DL extend to a position above upper surfaces of the semiconductor layers AS

so as to form the drain electrodes SD1. Further, the source electrodes SD2 are formed in a space-apart manner from the drain electrodes SD1 by a channel length of the thin film transistor TFT.

[0044]

These source electrode SD2 is slightly extended from the semiconductor layer AS surface to an upper surface of the insulation film at the pixel region side thus forming a contact portion CT for establishing the connection with the pixel electrode PX described later.

[0045]

Here, a thin layer doped with impurities of high concentration is formed at interfaces between the semiconductor layer AS and the drain electrode SD1 as well as the source electrode SD2 and this layer functions as a contact layer.

[0046]

The contact layer is formed such that at the time of forming the semiconductor layer AS, the impurity layer of high concentration is already formed on a surface of the semiconductor layer AS and, using a pattern of the drain electrode SD1 and the source electrode SD2 formed on an upper surface of the impurity layer as masks, the impurity layer exposed from the masks is etched so as to form the contact layer.

[0047]

On the surface of the transparent substrate SUB1 on which

the thin film transistors TFT, the drain signal lines DL, the drain electrodes SD1 and the source electrodes SD2 are formed in the above-mentioned manner, a protective film PAS formed of a low-dielectric insulation film made of resin or the like, for example, is formed. The protective film PAS is provided for preventing the thin film transistors TFT from coming into direct contact with the liquid crystal and hence, can prevent the deterioration of characteristics of the thin film transistors TFT.

[0048]

On an upper surface of the protective film, the pixel electrodes PX are formed. The pixel electrode PX is formed of a light-transmitting conductive film made of, for example, ITO (Indium Tin Oxide), ITZO (Indium Tin Zinc Oxide), IZO (Indium Zinc Oxide),  $\text{SnO}_2$  (Tin Oxide),  $\text{In}_2\text{O}_3$  (Indium Oxide) or the like.

[0049]

The pixel electrode PX is constituted of a mass which is formed of a large number of electrodes (sub pixels) having a circular pattern, for example.

[0050]

That is, the pixel electrode PX is constituted such that the circular sub pixels are formed in a matrix array. Each sub pixel is electrically connected with other neighboring four sub pixels with each other through light-transmitting conductive films having a relatively narrow width which are integrally

formed with the sub pixels.

[0051]

In other words, the pixel electrode PX is formed in a shape in which a large number of openings having a diamond shape (respective sides having an arcuate shape directing inwardly) which are arranged in a matrix array are formed in a light-transmitting conductive film formed over the most portion of the pixel region in a planar shape.

[0052]

The pixel electrode PX has a portion of a periphery thereof electrically connected with the source electrode SD2 of the thin film transistor TFT through the contact portion CT formed on the protective film PAS.

[0053]

Then, on an upper surface of the transparent substrate SUB1 on which the pixel electrodes PX are formed in the above-mentioned manner, an orientation film ORI1 is formed such that the orientation film ORI1 also covers the pixel electrodes PX. The orientation film ORI1 is a film which is brought into direct contact with the liquid crystal and determines the initial orientation direction of molecules of the liquid crystal.

[0054]

Further, on a surface of the transparent substrate SUB1 opposite to the liquid crystal, a polarizer POL1 is formed.

[0055]

On the other hand, on a liquid-crystal-side surface of the transparent substrate SUB2, a black matrix BM is formed such that the black matrix BM defines respective pixel regions. That is, the black matrix BM is formed in a pattern that openings are formed in the black matrix BM except for peripheral portions of respective pixel regions (including portions which cover the thin film transistors TFT). Due to such a constitution, the display contrast can be enhanced and the deterioration of characteristics of the thin film transistors TFT can be obviated.

[0056]

On the surface of the transparent substrate SUB2 on which the black matrix BM is formed, color filters FIL are formed such that the color filters FIL cover the openings formed in the black matrix BM. The color filters FIL are constituted of filters of respective colors, for example, red(R), green (G) and blue (B). The color filters are formed in an arrangement such that the red filters, for example, are commonly formed on a group of respective pixel regions which are arranged in parallel in the y direction, while groups of pixel regions which are sequentially arranged close to each other in the x direction are arranged in order of red (R), green (G), blue (B), red (R), ... starting from the above-mentioned group of pixel regions of red (R).

[0057]

Then, a leveling film OC is formed such that the leveling

film OC also covers the black matrix BM and the color filters FIL. On portions of the leveling film OC which face the centers of respective sub pixels at the transparent substrate SUB1 side, cruciform projecting portions PRJ are formed such that the projecting portions PRJ intersect the portions.

[0058]

That is, as shown in Fig. 1 in which the leveling film OC is overlapped to respective sub pixels of the pixel electrode PX, the cruciform projecting portions PRJ are formed such that out of the cruciform projecting portions PRJ, for example, one one-stroke shape projecting portion PRJ1 is substantially aligned with the polarization axis direction D1 of the polarizer POL1 at the transparent substrate SUB1 side, and another one-stroke shape projecting PRJ2 is substantially aligned with the polarization axis direction D2 of the polarizer POL2 described later at the transparent substrate SUB2 side. Advantageous effects brought about by the cruciform projecting portions PRJ having such a constitution are explained in detail later.

[0059]

Further, as another embodiment, in place of the above-mentioned cruciform projecting portions PRJ, cruciform recessed portions DNT may be formed. This constitution also can obtain the substantially same advantageous effects.

[0060]

On a surface of the leveling film OC which is formed in the above-mentioned manner, a counter electrode CT which is formed of a transparent conductive film is formed. To the counter electrode CT, signals which become reference with respect to the video signal supplied to the pixel electrodes PX are supplied.

[0061]

Then, on portions of the counter electrode CT which face the centers of respective sub pixels at the transparent substrate SUB1 side, that is, on the intersecting portions of the cruciform projecting portions PRJ, protruding portions PRT formed of a resin material or the like, for example, is formed.

[0062]

Further, an orientation film ORI2 is formed on the counter electrode CT such that the orientation film ORI2 also covers the protruding portions PRT. The orientation film ORI2 is a film which is brought into direct contact with the liquid crystal and determines the initial orientation direction of molecules of the liquid crystal.

[0063]

In the above-mentioned embodiment, the sub pixels which constitute the pixel electrode PX are formed into a substantially circular shape. However, the sub pixels may be formed into a substantially rectangular shape as shown in Fig. 5. That is, with respect to the pixel electrode PX, in a conductive layer formed in a planar shape, a plurality of elongated holes LP which

are intermittently arranged in parallel in the x direction and a plurality of elongated holes LP which are intermittently arranged in parallel in the y direction are formed, wherein a rectangular pattern which uses portions corresponding to four elongated holes LP arranged close to each other as sides thereof is connected with other neighboring patterns by way of corners thereof.

[0064]

Here, by providing such a constitution to the pixel electrode PX, the directions of electric fields which are generated on the sub pixels differ and hence, the directions of the polarization axes of the polarizers and the extending directions of the recessed portions and projecting portions differ from each other. This matter will be explained later.

[0065]

<< Observation >>

Here, the extending directions of the projecting portions PRJ or the recessed portions DNT formed at the transparent substrate SUB2 side are explained in conjunction with Fig. 6.

[0066]

First of all, Fig. 6 describes the extending directions of the projecting portions PRJ or the recessed portions DNT by classifying into two cases, wherein the chiral material is not contained in the liquid crystal in one case 6A and the chiral material is contained in the liquid crystal in another case 6B.



This is because when the chiral material is contained in the liquid crystal, the liquid crystal molecules exhibit the twisted behavior.

[0067]

Here, it is possible to detect whether the chiral material is contained in the liquid crystal of the liquid crystal display device or not in a following manner. First of all, the liquid crystal inside the liquid crystal display device is taken out by disassembling the liquid crystal display device and, thereafter, the liquid crystal is filled in a so-called wedge-like cell (cano cell). With respect to the liquid crystal which contains the chiral material, when the cell is observed using a polarization microscope, a stripe pattern having a particular color tone change is observed and hence, it is found that the cell is partitioned by parallel lines (disclination) a so-called Grandjean-cano walls (see literature: Ekisho (liquid crystal), Kisohe (fundamental part), Baifukan, page 227).

[0068]

In Fig. 6, there is shown a case in which the first stage and the second stage use the liquid crystal containing no chiral material and the third stage and the fourth stage use the liquid crystal containing chiral material. Further, in respective stages, in the drawing, the left side 6X indicates the direction of electric field in the sub pixels at the TFT side (transparent substrate SUB1 side), the center 6Y indicates the structure of

protruding portions or the like at the CF side (transparent substrate SUB2 side), and the right side 6Z indicates the direction of polarization axes of respective polarizers.

[0069]

Here, the direction of electric field in the sub pixels depends on the shape of the sub pixels of the pixel electrode PX. With respect to the directions of polarization axes of respective polarizers, one direction of polarization axis indicates the direction of polarization axis of the polarizer POL1 provided to the surface of the transparent substrate SUB1 opposite to the liquid crystal and another direction of polarization axis indicates the direction of polarization axis of the polarizer POL2 provided to the surface of the transparent substrate SUB2 opposite to the liquid crystal.

Here, in Fig. 6, all drawings are views as viewed from the observation side of the liquid crystal display device.

[0070]

That is, the first stage shows the case in which the chiral material is not contained in the liquid crystal and hence, the first stage shows the constitution of the above-mentioned essential part of the embodiment. The direction of electric field assumes  $45^\circ$ ,  $135^\circ$ ,  $225^\circ$ ,  $315^\circ$  with respect to the x axis depending on the shape of the sub pixels of the pixel electrode PX and hence, the directions of polarization axes of the respective polarizers are set such that the direction of

polarization axis of one polarizer is set within a range of  $\pm 30^\circ$  with respect to the x axis, while the direction of polarization axis of another polarizer is set to  $90^\circ$  with respect to the x axis. On the other hand, by setting the respective extending directions of the recessed portions or the projecting portions such that one extending direction falls within a range of  $\pm 30^\circ$  with respect to the x axis and another extending direction assumes  $90^\circ$  with respect to the x axis, it is possible to obviate the generation of so-called extinction pattern.

[0071]

The second stage shows the case in which the chiral material is not contained in the liquid crystal and the shape of the sub pixels of the pixel electrode PX is set to a shape shown in the previously-mentioned Fig. 5. In this case, the directions of electric field assume  $0^\circ$ ,  $90^\circ$ ,  $180^\circ$ ,  $270^\circ$  with respect to the x axis. In this case, with respect to the directions of polarization axes of the respective polarizers, one direction of polarization axis is set to a value within a range of  $15^\circ$  to  $75^\circ$  with respect to the x axis, while another direction of polarization axis is set to  $90^\circ$  with respect to the x axis. On the other hand, by setting the respective extending directions of the recessed portions or the projecting portions such that one extending direction falls within a range of  $15^\circ$  to  $75^\circ$  with respect to the x axis and another extending direction assumes  $90^\circ$  with respect to the x axis, it is possible to obviate the

generation of the above-mentioned so-called extinction pattern.

[0072]

The third stage shows the case in which the chiral material is contained in the liquid crystal and the directions of electric field on the sub pixels of the pixel electrode PX assume  $45^\circ$ ,  $135^\circ$ ,  $225^\circ$ ,  $315^\circ$  with respect to the x axis. In this case, with respect to the directions of polarization axes of the respective polarizers, one direction of polarization axis is set to a value within a range of  $15^\circ$  to  $75^\circ$  with respect to the x axis, while another direction of polarization axis is set to  $90^\circ$  with respect to the x axis. On the other hand, by setting the respective extending directions of the recessed portions or the projecting portions such that one extending direction falls within a range of  $15^\circ$  to  $75^\circ$  with respect to the x axis and another extending direction assumes  $90^\circ$  with respect to the x axis, it is possible to obviate the generation of the above-mentioned so-called extinction pattern.

[0073]

The fourth stage shows the case in which the chiral material is contained in the liquid crystal and the directions of electric field on the sub pixels of the pixel electrode PX assume  $0^\circ$ ,  $90^\circ$ ,  $180^\circ$ ,  $270^\circ$  with respect to the x axis. In this case, with respect to the directions of polarization axes of the respective polarizers, one direction of polarization axis is set to a value within a range of  $\pm 30^\circ$  with respect to the x axis, while another

direction of polarization axis is set to  $90^\circ$  with respect to the x axis. On the other hand, by setting the respective extending directions of the recessed portions or the projecting portions such that one extending direction falls within a range of  $\pm 30^\circ$  with respect to the x axis and another extending direction assumes  $90^\circ$  with respect to the x axis, it is possible to obviate the generation of the above-mentioned so-called extinction pattern.

[0074]

From the above, it is found that the extending directions of the recessed portions or projecting portions depend on the directions of polarization axes of respective polarizers irrespective of the presence or absence of the chiral material in the liquid crystal and the directions of electric fields on the sub pixels of the pixel electrode PX.

[0075]

That is, when the liquid crystal molecules are tilted in parallel with respect to the substrates, with the provision of the above-mentioned projecting portions PRJ or the recessed portions DTN which are formed in the direction substantially equal to the directions of polarization axes of the respective polarizers, it is possible to obstruct the tilting of the liquid crystal molecules along the polarization axes of the respective polarizers in a concentrated manner. As a result, it is estimated that the generation of the extinction pattern can be prevented.

[0076]

Embodiment 2.

Fig. 7 is a constitutional view showing another embodiment of the liquid crystal display device according to the present invention and is also a plan view obtained by viewing the transparent substrate SUB2 from the liquid crystal side.

[0077]

In this case, the directions of polarization axis of the polarizers POL1 or POL2 are set to values within a range of  $-30^{\circ}$  to  $30^{\circ}$  with respect to the direction of the x axis (running direction of the gate signal lines GL) and hence, one projecting portions PRJ1 of the projecting portions PRJ which correspond to respective sub pixels of the pixel electrode PX are also set within a range of  $-30^{\circ}$  to  $30^{\circ}$ . Accordingly, in this embodiment, the projecting portions PRJ1 and the projecting portions PRJ1 of another pixel region which is arranged close to the former pixel region in the lateral direction are connected to each other linearly. Further, since the other projecting portions PRJ2 assume the direction orthogonal to the direction of the projecting portions PRJ1, in the same manner, the projecting portions PRJ2 and the projecting portions PRJ2 of another pixel region laterally arranged close to the former pixel region are connected to each other linearly.

[0078]

Fig. 8 is a constitutional view showing another embodiment of

the liquid crystal display device according to the present invention and also is a plan view obtained by viewing the transparent substrate SUB2 from the liquid crystal side.

[0079]

In this case, the directions of polarization axis of the polarizers POL1 or POL2 is set to values within a range of  $15^{\circ}$  to  $75^{\circ}$  with respect to the x axis (running direction of the gate signal lines GL) and hence, one projecting portions PRJ1 of the projecting portions PRJ which correspond to respective subpixels of the pixel electrode PX are also set within a range of  $15^{\circ}$  to  $75^{\circ}$ . Accordingly, in this embodiment, the projecting portions PRJ1 and the projecting portions PRJ1 of another pixel region which is obliquely arranged close to the former pixel region are connected to each other linearly. Further, since the other projecting portions PRJ2 assume the direction orthogonal to the direction of the projecting portions PRJ1, in the same manner, the projecting portions PRJ2 and the projecting portions PRJ2 of another pixel region which are obliquely arranged close to the former pixel region are connected to each other linearly.

[0080]

Embodiment 4.

Fig. 9 is a constitutional view showing another embodiment of a liquid crystal display device according to the present invention and is a view which shows a cross section of the

protruding portion PRT corresponding to the sub pixel of the pixel electrode PX.

[0081]

This drawing explicitly describes that in place of the projecting portions PRJ which extend in a cruciform about the protruding portions PRT, the recessed portions DNT are formed in the leveling film OC.

[0082]

Although only one sub pixel is shown as the pixel electrode PX in the drawing for the sake of brevity, in the actual liquid crystal display device, with respect to peripheries of the projecting portions PRJ corresponding to other sub pixels, the recessed portions DNT which extend in a cruciform are formed about the protruding portions PRT.

[0083]

Embodiment 5.

Fig. 10 is a constitutional view showing another embodiment of the liquid crystal display device according to the present invention and corresponds to Fig. 9.

[0084]

The constitution which makes this embodiment different from the embodiment shown in Fig. 9 lies in that the protruding portions PRT and the counter electrode CT are formed in a reversed manner. That is, the protruding portions PRT are formed on an upper surface of the leveling film OC in which the recessed



portions DNT are formed and the counter electrode CT is formed on a surface of the leveling film OC such that the counter electrode CT also covers the protruding portions PRT.

[0085]

Embodiment 6.

Fig. 11 is a constitutional view showing another embodiment of the liquid crystal display device according to the present invention and corresponds to Fig. 10.

[0086]

The constitution which makes this embodiment different from the embodiment shown in Fig. 10 lies in that the projecting portions PRJ are formed in place of the recessed portions DNT.

[0087]

Embodiment 7.

In the above-mentioned respective embodiments, the pixel electrode PX side is constituted of a large number of sub pixels and the protruding portions PRT are formed on the counter electrode CT side. However, it is needless to say that by forming a large number of sub pixels on the counter electrode CT side and by forming the protruding portions on the pixel electrode PX side, it is possible to obtain the substantially same advantageous effects. This is because although signals different from each other are supplied to the pixel electrodes PX and the counter electrode CT, there is no such difference with respect to respective electrodes in the behavior of the

liquid crystal.

[0088]

The above-mentioned respective embodiments may be used in a single form or in combination. This is because it is possible to obtain the advantageous effects of the respective embodiments in a single form or synergistically.

[0089]

As can be clearly understood from the foregoing explanation, according to the liquid crystal display device of the present invention, it is possible to obviate the generation of extinction pattern.